Monitoring the early stage of ozone hole formation using Aura MLS data

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Introduction

In August 2008 the Antarctic ozone hole appears very small before it jumps to a large size in the beginning of September in the NOAA satellites' SBUV/2 observation. This feature is very different from the same time period in 2007, though the 2008 polar temperature is colder than that in 2007. Why is the ozone hole so small in August 2008?

(1) Data problem?

The Antarctic ozone hole is usually represented by total ozone column less than 220 DU. The total ozone measuring instruments, such as SBUV and OMI, can not measure ozone in polar night. Therefore, detection of early stage of ozone hole formation is sometimes hindered. We use Aura MLS v2.2 ozone profile data to calculate polar stratospheric column ozone and compare its evolution in the same period of the two years.

2) More concentric polar vortex?

Ozone hole formation may be affected by the shape and center location of polar vortex. Because heterogeneous ozone destruction requires sunlight, an off-pole or elongated vortex may be exposed to sunlight earlier than a polar concentric vortex in the beginning of SH springtime. We compare features of SH polar vortex, as well as sun-lit PSC areas between August 2008 and 2007.

(3) Other factors (initial ozone , ClO, etc.)?

We examine polar stratospheric ozone prior to ozone hole formation and ClO variations using Aura MLS data.

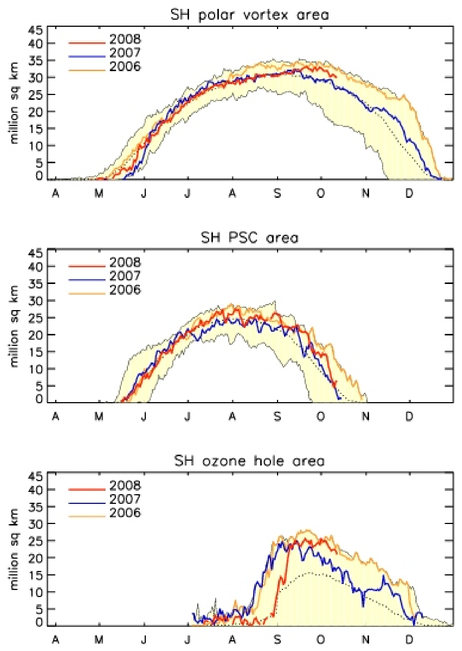

Fig.1 Areas of SH polar vortex (upper panel, here defined as the absolute PV value greater than 32 PVU at 450K isentropic surface), polar stratospheric clouds or PSC (middle panel, here defined as temperature colder than 195K at 450K isentropic surface), and ozone hole (lower panel, total ozone less than 220 DU). PV and temperature data are from the NCEP/NCAR Reanalysis, ozone data are from NCEP/CPC ozone analysis (mainly NOAA-17 SBUV/2, ATOVS is adjusted to SBUV/2 to fill polar night gaps).

Shaded areas indicate ranges of year-to-year differences. Dotted curves indicate 1979-2008 average. Colored curves indicate daily area evolutions of recent 3 years. Note that in August the vortex areas are about the same in 2008 and 2007, and the PSC area in 2008 is larger than that in 2007. However, area of ozone hole in August 2008 is very small compared with that in 2007.

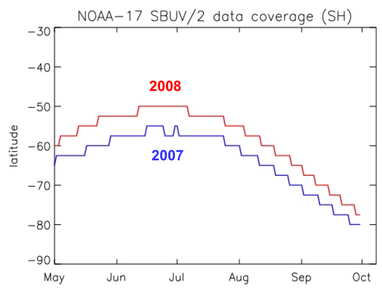

Fig.2 Southern boundaries of NOAA-17 SBUV/2 ozone data coverage. There are no data in the high latitudes of polar night. In 2008 the data boundary retreated ~5 degree northward due to the satellite orbit drift.

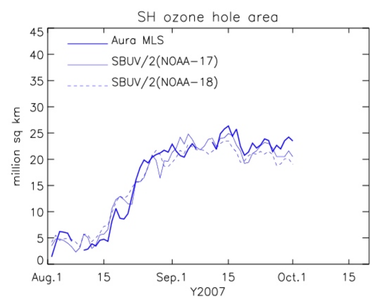

Fig. 3 Because SBUV/2 data do not cover polar night, we use integrated Aura MLS ozone profile data (v2.2) from215 hPa to 0.1 hPa to represent stratospheric ozone column, and redefine ozone hole as the stratospheric column ozone less than 210 DU. The MLS ozone hole area (thick curve) is generally comparable to the SBUV/2 ozone hole area (thin curve) in August and September 2007.

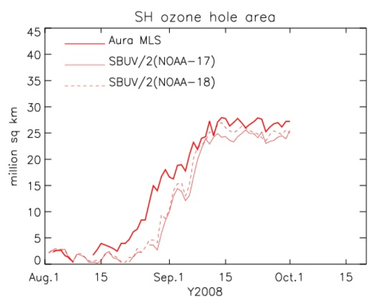

Fig. 4 The MLS ozone hole area (thick curve) is apparently larger than the SBUV/2 ozone hole area (thin curve) in August and September 2008. It means that the very small ozone hole in August 2008 in Fig.1 is partly attributed to the SBUV/2 data problem. NOAA-17 has drifted ~5 degree north in 2008, which resulted in less data coverage in SH polar region.

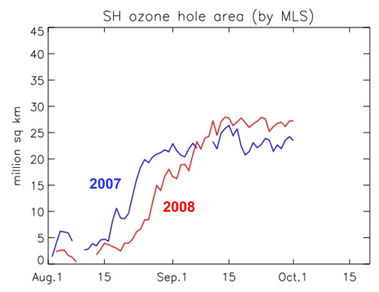

Fig. 5 The MLS ozone hole area in August 2008 is still smaller than that in August 2007.

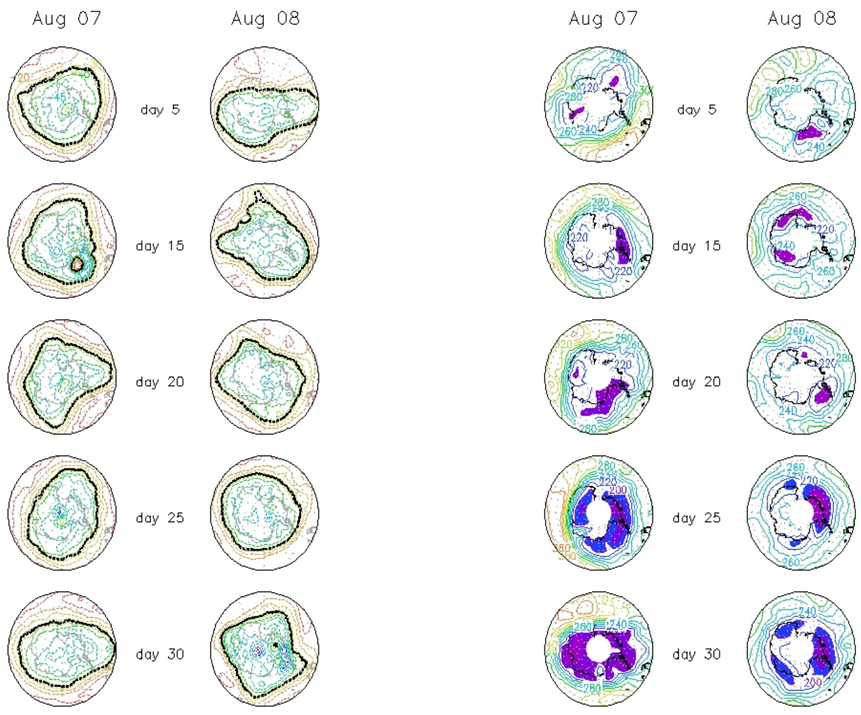

Fig.6 Comparisons of 2007 and 2008 August polar vortex (left two columns, black curves indicate vortex walls defined as -32 PVU contour at 450K) and ozone hole (right two columns, shaded area indicate stratospheric ozone column less than 210 DU calculated from MLS data) at selected days.

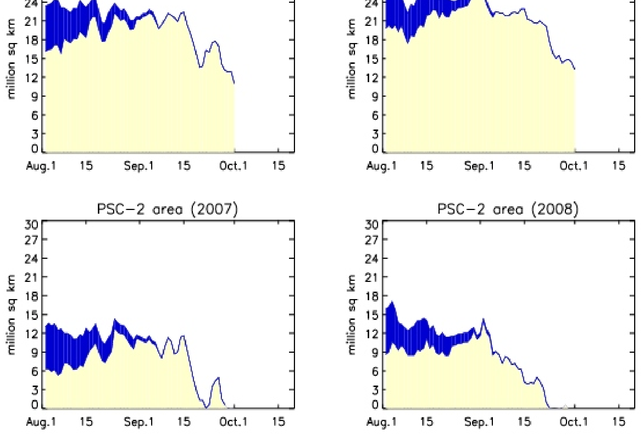

Fig. 7 As heterogeneous ozone depletion requires sunlight, we compare total and sun-lit PSC area in 2007 and 2008. The dark blue areas indicate portions of PSC area without sunlight. Those PSC areas are all based on 450K (~70 hPa) temperature. PSC-1 area is defined as T < 195K and PSC-2 area is defined as T < 188K. Note that both sun-lit PSC-1 and PSC-2 areas in August 2008 are slightly larger than those in August 2007.

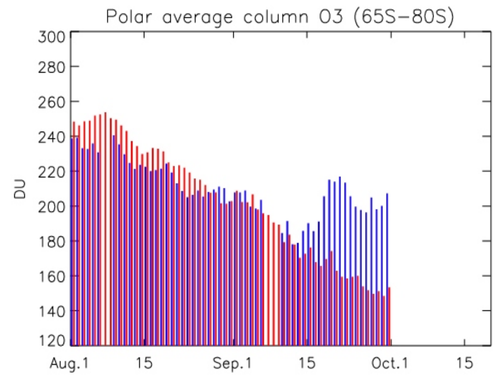

Fig.8 Comparison of daily polar average MLS stratospheric column ozone in 2007 (blue) and 2008 (red). The polar average is from 65S to 80S because there are few MLS data beyond 80S. In some days of 2007 the data are missing. At the beginning of August, polar ozone in 2008 is 10-20 DU more than that in 2007. Meanwhile, the polar ozone decease rate in 2008 is faster than that in 2007, that is consistent with the larger PSC area in 2008.

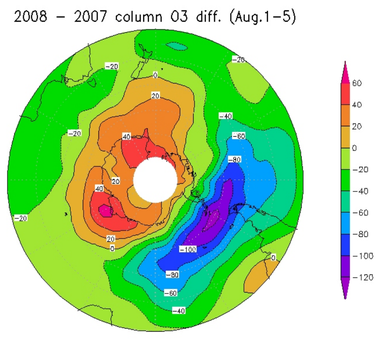

Fig.9 Stratospheric column ozone difference between 2008 and 2007 in the beginning of August (Aug. 1-5 average). In 2008, there is more ozone in the SH polar region in the early stage of ozone hole formation than in 2007. Therefore, a much smaller ozone hole is observed in August 2008, even though the lower stratosphere is colder and the ozone decrease rate is faster.

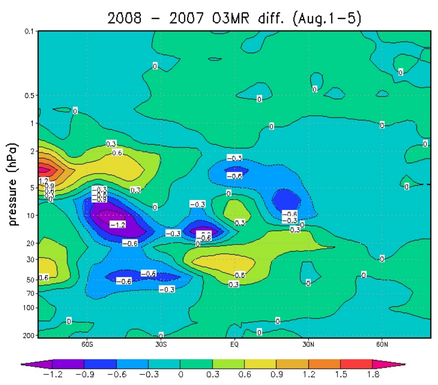

Fig.10 Same as Fig.9 except for zonal mean ozone mixing ratio difference. MLS ozone mixing ratio data show that there is more ozone in SH polar region (60S-80S) throughout the stratosphere in the beginning of August 2008.

Fig.11 Polar average ClO mixing ratio (ppbv) of August 2007. The ClO is from MLS v2.2 data. No plot in Aug. 1-9, 2007 because the data are either of poor quality or missing.

Fig.12 Same as Fig.11 except for August 2008.

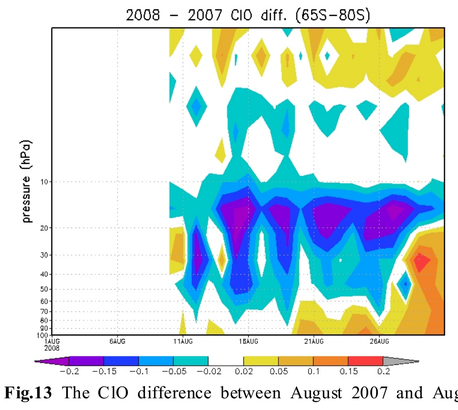

Fig.13 The ClO difference between August 2007 and August 2008. Note that less ClO is observed in the lower stratosphere in August 2008 till the end of month.

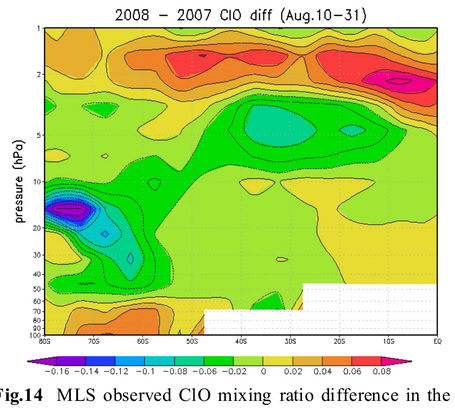

Fig.14 MLS observed ClO mixing ratio difference in the early stage of ozone hole formation between 2008 and 2007. The time average is from August 10 to August 31.

Conclusions

- The larger PSC area and smaller ozone hole in August 2008 than those in the same period of 2007 are investigated by using Aura MLS data and other meteorological data.
- In the beginning of August 2008, the SH polar ozone is 10-20 DU more than that in 2007. Therefore, even ozone depletion occurs at the same rate, ozone hole would appear later in 2008.
- In August there is less ClO in the lower stratosphere in 2008 than in 2007, which means less ozone is depleted in August 2008.
- The more concentric polar vortex in late August 2008 is less likely responsible for the smaller ozone hole.
- Due to the orbit drift of NOAA-17, the SBUV/2 ozone data coverage in SH polar region is ~ 5 degree less in 2008 than in 2007. The ozone hole area in August 2008 calculated by SBUV/2 data is underestimated. MLS ozone data are very useful resources for monitoring early stage of ozone hole formation.